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DETROIT ARSENAL
Center Line, Michigan

POWER PLANT LABORATORY
Laboratories Division

TITLE OF REPORT: COOLING AND PERFORMANCE CHARACTERISTICS OF THE XM-551 ARMORED RECONNAISSANCE AIRBORN ASSAULT VEHICLE.

REPORT NO. 7746 (Final) DATE: 17 April 196

EXPENDITURE ORDER 3517-03-32

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ABSTRACT

Report No. 7746

1. Purpose: Determine at 115 F ambient the performance and cooling characteristics of the XM-551 vehicle.

2. Method: High-ambient performance and cooling tests were conducted at full-rack, 3rd driving range with a 3-5 mph headwind.

3. Results and Conclusions: a. Maximum observed sprocket horsepower was 182 at 2797 rpm engine speed with the transmission in 3rd driving range, lockup. b. The vehicle at full-fuel rack cooled at 115 F ambient with the transmission in third driving range at all design operating speeds. The coolant thermostat was blocked open and the fan automatic speed control removed. The highest lockup temperatures were obtained at an engine speed of 2798 rpm. Engine sump oil, coolant leaving the engine and oil leaving the transmission were 254 F, 197 F and 235 F at 115 F ambient. The highest converter temperatures were obtained at the lowest converter ratio. At a converter speed ratio of .36, engine sump oil, coolant leaving the engine and oil leaving the transmission were 261 F, 215 F and 300 F at 115 F ambient. At a converter speed ratio of .56, engine sump oil, coolant leaving the engine, and oil leaving the transmission were 255 F, 207 F and 262 F at 116 F ambient. A .56 converter ratio is the ratio at the minimum design vehicle operating speed of $2\frac{1}{2}$ miles per hour with the transmission in first driving range.

DETROIT ARSENAL
Laboratories Division

Report No. 7746 (Final)

Date: 17 April 1963

PROJECT TITLE: Cooling and Performance Characteristics of the XM-551 Armored Reconnaissance Airborn Assault Vehicle

INTRODUCTION

A program was initiated to determine the adequacy of the cooling system, and the performance characteristics for the XM-551 vehicle at 115 F ambient. The cooling system was designed to prevent the power package temperatures from exceeding design limits. The power package was composed of a liquid-cooled, compression ignition engine and a semi-automatic transmission. This report covers the cooling and performance testing and the evaluation of the results.

OBJECT

Determine at 115 F ambient the performance and cooling characteristics of the XM-551 vehicle.

SUMMARY

1. Performance Tests

a. Maximum observed XM-551 sprocket horsepower was 182 at 2797 rpm engine speed with the transmission in third driving range lockup.

b. Specific fuel consumption varied from .46 pound of fuel per sprocket brake horse power hour at 2197 rpm engine speed with the transmission in third driving range lockup, to .73 pound of fuel per sprocket brake horsepower hour with the transmission in third driving range converter at a .31 speed ratio. At a .56 converter speed ratio, fuel consumption was .54 pound of fuel per brake horsepower hour.

2. Cooling Tests

a. XM-551 vehicle at full-fuel rack cooled at 115 F ambient at all engine speeds with the transmission in third driving range lockup. All cooling results were obtained with the coolant thermostat blocked open and the fan automatic speed control removed. The highest lockup temperatures were obtained at maximum engine speed. At an engine speed of 2788 rpm, engine sump oil, coolant leaving the engine and oil leaving the transmission, were 254 F, 197 F and 235 F at 115 F ambient.

b. XM-551 vehicle at full-fuel rack cooled at 115 F ambient at all converter speed ratios down to and including .36 with the transmission in third driving range. The highest temperatures were obtained at the lowest converter ratio. At a converter speed ratio of .36, engine sump oil, coolant leaving the engine and oil leaving the transmission, were 261 F, 215 F and 300 F at 115 F ambient. At a converter speed ratio of .56, engine sump-oil, coolant leaving the engine and oil leaving the transmission, were 255 F, 207 F and 262 F at 116 F ambient.

> The converter ratio is .56 at the minimum required sustained vehicle operating speed of $2\frac{1}{2}$ miles per hour with the transmission in first driving range.

3. Vehicle Deficiencies

a. During testing, the nickel cadmium batteries were found to be covered with electrolyte residue from boiling over.

b. Near the end of the cooling tests a fuel leak developed in the forward portion of the left fuel cell.

c. The fuel tank filler cap had three locking lugs. Occasionally when installing the cap only two of the lugs would engage.

d. During preliminary testing with the vehicle exhaust system connected to the laboratory exhaust blower the engine turbocharger leaked oil.

CONCLUSION

The XM-551 vehicle at full-fuel rack cooled at 115 F ambient with the transmission in third driving range at all design operating speeds (coolant thermostat blocked open and the fan automatic speed control removed).

RECOMMENDATIONS

It is recommended that the XM-551 vehicle cooling characteristics be determined with the engine coolant thermostat and fan automatic speed control in operation.

TEST MATERIAL

1. XM-551 Armored Reconnaissance Airborn Assault Vehicle, R and D Pilot No. 2, U.S. Army 12 Z 287. The vehicle is shown set up in the test cell in Figures 1 through 4. Figure 1 shows the right front and Figure 2 shows the front view of the vehicle. Figure 3 shows the right rear of the vehicle, gun to the rear, and Figure 4 shows the right rear of the vehicle, gun forward. Figures 5 through 7 show the power package. Figure 8 shows the radiator. Figures 9 and 10 show the power package installed in the vehicle. Vehicle components concerned in the tests are described below:

a. Compression-ignition engine

Code E-177 engine was a 318.6 cubic inch, liquid cooled, V-6, two-cycle engine. The engine was super charged with both a Roots blower and a turbo-charger. The engine oil was cooled by an oil-to-coolant heat exchanger.

b. Semi-automatic transmission

Code T-23 transmission included a hydraulic torque converter with a lockup clutch. The planetary range gearing in combination with the steer and output planetary sets provide four forward and two reverse driving ranges. The transmission also incorporated geared steer, clutch brake, and pivot steer systems and full multiple wet-plate brakes. The transmission included the final drive gears. The transmission oil was cooled by an oil-to-coolant heat exchanger. The transmission

overall gear ratios in each driving range were as follows:

(1) First - 19.83:1

(2) Second - 13.49:1

(3) Third - 7.19:1

(4) Fourth - 3.20:1

(5) Reverse 1 - 15.18:1

(6) Reverse 2 - 6.75:1

c. Cooling fan, vane-axial type with automatic speed control.

d. Radiator, aluminum, cross-flow type with independently mounted expansion tank.

e. Engine and transmission oil heat exchangers, oil-to-coolant type mounted on the right side of the engine.

f. Grilles, ballistic type.

2. Fuel, VV-F-800, Grade DF-2 dated 17 December 1954.

3. Oil, MIL-L-2104A, Supplement 1, Grades 10 and 30.

4. Coolant, tap water with rust inhibitor. Three 12-ounce cans of Code O-5 rust inhibitor were added to one filling of the cooling system.

TEST EQUIPMENT

Test cell No. 5, Bldg. 212, with associated equipment and instrumentation.

The cell is capable of operating at temperatures from outside ambient to 160 F, with winds from 3 to 7 miles per hour. Power absorption equipment is located in two rooms on either side of the test cell. See Figures 1 through 4. Included in the cell equipment is an automatic warning and shutdown system which will sound an alarm as a warning, and stop

the test if a temperature or pressure becomes critical. Automatic data print-out for temperature and pressures is used. As many as 400 pressure and temperature variables can be printed out in five minutes. Figure 11 shows the control panel in the test cell control room. Included in the cell was the following equipment:

1. Thermocouples, 50, iron constantan, ISA type "Y", with Bristol meter and a semi-automatic electrical typing system for recording.

a. Air, ambient, (4)

b. Air, entering inlet grille (6)

c. Air, entering radiator, (8)

d. Air, leaving radiator, (8)

e. Air, leaving exit grille, (6)

f. Air, entering air cleaner

g. Air, entering turbocharger

h. Air, air box

i. Air, battery box

j. Air, above transmission, left

k. Air, above transmission, right

l. Coolant, leaving engine right bank

m. Coolant, leaving engine left bank

n. Coolant, entering radiator

o. Coolant, leaving radiator

p. Coolant, entering oil coolers

q. Coolant, leaving oil coolers

r. Oil, engine sump

s. Oil, engine turbine drain

t. Oil, entering transmission

u. Oil, leaving transmission

v. Fuel, leaving tank

w. Fuel, entering engine

2. Thermocouples, 7, chromel alumel with Brown push button indicating meter located as follows:

a. Gases, exhaust, entering turbocharger

b. Gases, exhaust, leaving each cylinder, (6)

3. Pressure transducers, 4, Vibratron digital gage, B. J. Electronics, Borg-Warner Corporation with semi-automatic typing system located as follows:

a. Coolant, surge tank, 0 to 30 psi

b. Oil, engine gallery, 0 to 160 psi

c. Oil, transmission main, 0 to 400 psi

d. Oil, entering transmission, 0 to 160 psi

4. Pressure gage, 0 to 160 psi, Bourdon Type, Marsh Instrument Co., indicating fuel pressure entering engine.

5. Manometer, indicating ambient air pressure in the 0 to 30 inches water range.

6. Manometer indicating air box pressure in the 0 to 30 inches mercury range.

7. Force gage measuring equipment, General Electric (2) range 0 to 87,000 lb. ft torque with two Brown indicating units.

8. Absorption dynamometers with gear boxes (2) General Electric.

The maximum stall torque is 68,000 lb. ft. Maximum torque at 15 rpm is 44,000 lb. ft. Maximum shaft speed at high torque ratio is 360 rpm and the maximum shaft speed in direct drive is 3000 rpm.

9. Chronotachometer , Electric Time Company, range 0 to 7000 rpm, with adjustable over speed limit and four-pole synchronous generator for engine speed.

10. Chronotachometers (2) Electric Time Company, range 0 to 2000 rpm and Selsyn generators for absorption dynamometer speeds.

11. Carbon-monoxide detecting instrumentation, Mine Safety Appliances Company, range .000 to .150 percent carbon monoxide concentrations.

12. Combustible gas detecting instrumentation, David Instrument Division, David Equipment Company.

13. Velometer, Hastings for indicating test cell wind velocity.

14. Barometer, Central Scientific Company.

15. Engine fuel flow measuring system, Harvard Trip Balance, and Electric Time Company Timer.

TEST PROCEDURE

XM-551 vehicle cooling and performance tests were conducted in accordance with Power Plant Laboratory Test Program No. 575 dated 11 July 1962 (Inclosure 1) and directives from the project engineer. All tests were conducted at full-fuel rack in third driving range with a 3 to 5 mph headwind. The tracks were removed for testing. Coolant thermostat was blocked for maximum flow. The fan automatic speed control was removed. This speed control was designed to operate the fan only when cooling was required. The fan during testing operated at a constant fan shaft to engine crank shaft speed ratio. Engine stall speed was checked before and after each day's testing.

1. Vehicle performance tests were conducted at an ambient temperature of 115 ± 5 F. The length of each test was only the time required to record one complete set of data (10 to 15 minutes). Fuel was pumped to the engine from laboratory tanks. Tests were conducted under the following conditions:

a. Engine speed 2797 rpm, transmission in lockup

b. Engine speed 2601 rpm, transmission in lockup

c. Engine speed 2400 rpm, transmission in lockup

d. Engine speed 2197 rpm, transmission in lockup

e. Engine speed 2000 rpm, transmission in lockup

f. Transmission at .76 converter speed ratio

g. Transmission at .72 converter speed ratio

h. Transmission at .63 converter speed ratio

i. Transmission at .61 converter speed ratio

j. Transmission at .56 converter speed ratio

k. Transmission at .48 converter speed ratio

l. Transmission at .42 converter speed ratio

m. Transmission at .31 converter speed ratio

2. Vehicle cooling tests except Test 1 were conducted at an ambient temperature of 115 ± 1 F. Test 1 was conducted at the ambient temperature which caused the temperature of the oil leaving the transmission to stabilize at 300 F at a .3 converter speed ratio. Each test was conducted until all pertinant temperatures stabilized (30 to 90 minutes). Tests were conducted using fuel from the vehicle tanks. Tests were conducted under the following conditions:

a. Engine speed 2805 rpm, transmission in lock-up, turret facing to the rear (see Figure 3)

b. Engine speed 2599 rpm, transmission in lock-up, turret facing to the rear

c. Engine speed 2399 rpm, transmission in lock-up, turret facing to the rear

d. Engine speed 2206 rpm, transmission in lock-up, turret facing to the rear

e. Engine speed 2001 rpm, transmission in lock-up, turret facing to the rear

f. Transmission at .81 converter speed ratio, turret facing to the rear

g. Transmission at .71 converter speed ratio, turret facing to the rear

h. Transmission at .62 converter speed ratio, turret facing to the rear

i. Transmission at .52 converter speed ratio, turret facing to the rear

j. Transmission at .41 converter speed ratio, turret facing to the rear

k. Transmission at .31 converter speed ratio, turret facing to the rear

l. Transmission at .30 converter speed ratio, turret facing to the rear

m. Engine speed 2796 rpm, transmission in lock-up, turret facing forward (see Figure 4)

n. Engine speed 2798 rpm, transmission in lock-up, turret facing forward

o. Transmission at .40 converter speed ratio turret facing forward

p. Transmission at .36 converter speed ratio turret facing forward

RESULTS AND DISCUSSION

Results of XM-551 vehicle performance and cooling tests are discussed below:

1. Performance Tests

Performance results of the full-fuel rack tests are presented in Table I. Performance tests are referred to by the paragraph numbers they are listed under in the Test Procedure Section of the report. All values are observed. Test cell ambient temperature was 115 ± 5 F and fuel temperature 103 to 112 F for all tests. The transmission was in third driving range. The results are plotted in Figure 12.

a. Maximum observed sprocket brake horsepower was 182 at 2797 rpm engine speed with the transmission in lockup, Performance Test a. Design maximum engine operating speed is 2800 rpm. Specific fuel consumption for this test was .53 pound of fuel per sprocket brake horsepower hour.

b. Minimum specific fuel consumption was .46 pound of fuel per sprocket brake horsepower hour at 2197 rpm engine speed, Performance Test d. The transmission was in lockup. Observed sprocket horsepower was 165.

c. Minimum engine operating speed attempted with the transmission in lockup was 2000 rpm, Performance Test e. Observed sprocket horsepower was 151 at 2000 rpm engine speed. Specific fuel consumption for this test was .47 pound of fuel per sprocket brake horsepower hour.

d. Maximum engine operating speed was 2500 rpm to 2600 rpm with the transmission in converter. This was at a converter speed ratio of approximately .8. Observed sprocket horse power was 157 at 2486 rpm engine speed with the transmission at a converter speed ratio of .76, Performance Test f. Specific fuel consumption was .53 pound of fuel per sprocket brake horsepower hour.

e. Minimum design vehicle operating speed is $2\frac{1}{2}$ miles per hour in first driving range. This requires a converter speed ratio of .56. At .56 converter speed ratio with the transmission in third driving range (the driving range where all testing was performed) sprocket horsepower was 141, Performance Test j. Specific fuel consumption was .54 pound of fuel per brake horseppower hour.

f. Minimum convertor speed ratio attempted was .31, Performance Test m. Observed sprocket horsepower at .31 converter speed ratio was 102. Specific fuel consumption was .73 pound of fuel per brake horsepower hour.

2. Cooling Tests

Results of the full-fuel rack cooling tests are presented in Table II. Cooling tests are referred to by the paragraph numbers they are listed under in the Test Procedure Section of the report. All cooling results were obtained with the coolant thermostat blocked open and the fan automatic speed control removed. Design maximum temperatures for engine sump oil, coolant leaving the engine and oil leaving the transmission, were 285 F, 230 F and 305 F respectively. Temperature, power and speed data with the turret facing to the rear are plotted in Figure 13. These curves show that the higher cooling loads were encountered at the maximum and minimum engine speeds with the transmission in either lockup or converter. The transmission was in third driving range.

a. XM-551 vehicle cooled (operated without exceeding temperature limits) at an engine speed of 2805 rpm with the transmission in lockup, Cooling Test a. This was design maximum engine speed. Ambient temperature was 115 F. Engine sump oil, coolant leaving the engine and oil leaving the transmission, temperatures stabilized at 253 F, 195 F and 229 F. This test was conducted with the turret facing to the rear. With the turret facing forward, engine sump oil ran only 1 F hotter, coolant leaving the engine 1 F hotter and oil leaving the transmission, from 2 F cooler to 6 F hotter, Cooling Tests m and n. The two turret positions (forward and rear) were considered to be the two most adverse positions for cooling as they blocked the greatest portion of the inlet grille.

b. XM-551 vehicle cooled at an engine speed of 2001 rpm with the transmission in lockup, Cooling Test 1. This was the minimum engine operating speed attempted with the transmission in lockup. Ambient temperature was 115 F. Engine sump oil, coolant leaving the engine and oil leaving the transmission, temperatures stabilized at 243 F, 194 F and 219 F. This test was conducted with the turret facing to the rear.

c. XM-551 vehicle cooled with the transmission in converter at a speed ratio of .81, Cooling Test f. This was the maximum converter ratio attempted. Ambient temperature was 115 F. Engine sump oil, coolant leaving the engine and oil leaving the transmission, temperatures stabilized at 262 F,

207 F and 267 F. The turret was facing to the rear.

d. Minimum required sustained vehicle operating speed is 2½ miles per hour in first driving range. This requires a converter speed ratio of .56. A .56 converter speed ratio in third driving range is a point falling between Cooling Tests h and i. The cooling load varies a negligible amount from one gear range to another as long as the converter speed ratio is the same. XM-551 vehicle cooled with the transmission in converter at a speed ratio of .56. Ambient temperature was 116 F. Engine sump oil, coolant leaving the engine and oil leaving the transmission, temperatures were 255 F, 207 F and 262 F. This test was conducted with the turret facing to the rear.

e. XM-551 vehicle failed to cool with the transmission in converter at a speed ratio of a .31, Cooling Test k. Ambient temperature was 116 F. Engine sump oil and coolant leaving the engine tmmperatures stabilized at 268 F and 223 F. These temperatures were below the design maximum limits. Oil leaving the transmission temperature at 316 F, however, exceeded the design maximum limit of 300 F. The turret was facing to the rear for this test.

f. To find the exact converter speed ratio at which the oil leaving transmission temperature stabilized at 300 F and also to further check the influence of the turret facing forward, Cooling Test p was conducted. XM-551 vehicle cooled with the transmission in converter at a speed ratio of .36. Ambient temperature was 115 F. Engine sump oil, coolant leaving the engine and oil leaving the transmission, temperatures stabilized at 261 F, 215 F and 300 F. These temperatures were all within 2 F of the temperatures during the cooling test with the turret facing to the rear. For the comparative cooling data with the turret facing to the rear, an interpolation between Cooling Tests j and k must be made. A direct comparison can also be made between Cooling Test j with the turret facing to the rear and Cooling Test o with the turret facing forward. At a converter speed ratio of .40 to .41 engine sump oil, coolant leaving the engine and oil leaving the transmission, temperatures agreed within 2 F. Ambient temperatures were 115 to 116 F.

g. To determine the ambient temperature at which the oil leaving the transmission temperature would stabilize at 300 F at a .3 converter speed ratio, Cooling Test l was conducted. At 85 F ambient XM-551 vehicle cooled with the transmission in converter at a speed ratio of .30. Engine sump oil, coolant leaving the engine and oil leaving the transmission,

temperatures stabilized at 242 F, 192 F and 300 F. The turret was facing to the rear. At 116 F ambient the vehicle had cooled at .31 converter speed ratio with engine sump oil, coolant leaving the engine and oil leaving the transmission, temperatures of 268 F, 223 F and 316 F, Cooling Test k. Lowering the ambient temperature 31 F lowered the oil leaving the transmission temperature 16 F. Two factors were mainly responsible for this two-degree ambient temperature reduction required per one-degree transmission temperature reduction.

(1) As the ambient was lowered the engine developed more power and speeded up (sprocket speed constant). This put more heat into the transmission oil requiring a still lower ambient temperature for stabilization.

(2) The converter speed ratio was slightly lower (.30 versus .31) with its accompanying greater transmission inefficiency.

h. The turbocharger exhaust turbine inlet design maximum temperature was 1350 F. During testing the highest temperature recorded was 1000 F.

i. Fuel temperatures never stabilized during testing. Since the engine returned hot fuel to the tank, as the test progressed, the fuel entering the engine temperature continually increased. The maximum fuel temperature would therefore be expected just prior to complete fuel run-out after operating at full load for a considerable time. This test was not conducted. However, the temperature of the fuel entering the engine did reach 179 F at the end of Cooling Test k.

j. Battery air temperatures were as high as 183 F, Cooling Test k.

Vehicle Deficiencies

a. During testing the nickel cadmium batteries were found to be covered with electrolyte residue indicating boil-over. See Figure 14. Boiling of the battery electrolyte was also observed immediately after shutdown operation at 115 F ambient. High battery-box ambient temperature (183 F in Cooling Test k) combined with the battery heat generation during normal battery charging to cause this boiling of the electrolyte.

b. Near the end of the cooling tests a fuel leak developed in the forward portion of the left fuel cell.

c. The fuel tank filler cap had three locking lugs. Occasionally only two of the lugs engaged.

d. During preliminary testing, the vehicle exhaust system was connected to the laboratory exhaust blower. A slight negative pressure was produced. The engine turbocharger oil seal under these conditions leaked oil. The vehicle exhaust system was disconnected from the laboratory exhaust blower and allowed to exhaust into the cell for all remaining testing. No more oil leakage was encountered. Under field operation the turbocharger should not leak. However, with the vehicle operated in a maintenance shop with its exhaust system connected to the shop exhaust blower, this difficulty could be encountered.

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DETROIT ARSENAL
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Date: 17 April 1963 Report No. 7746 (Fi

PROJECT TITLE: COOLING AND PERFORMANCE CHARACTERISTICS OF THE XM-551 ARMORED RECONNAISSANCE AIRBORN ASSAULT VEHICLE

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LIST OF INCLOSURES

Report No. 7746 (Final)

POWER PLANT LABORATORY
Test Program No. 575

11 July 1962

TITLE: Cooling and Performance Test of Power Package for XM 551 Self-Propelled Vehicles

OBJECT

Determine adequacy of cooling system for power package in XM 551 self-propelled vehicle in preventing critical temperatures from exceeding specified limits at full power and vehicle ambient temperature of 115 F.

OUTLINE OF PROBLEM

A cooling system is being developed for the power package in XM 551 self-propelled vehicle. The purpose of the cooling system is to cool the engine coolant, engine oil, and transmission oil. An XM 551 vehicle is being submitted for tests at high vehicle ambient temperatures. The cooling system will be tested with engine at full power and with transmission in lock-up and converter ratios from 0.8 to 0.3. Ambient temperatures of the vehicle will be from 95 to 115 F. If cooling system is inadequate, tests will be conducted within limits of funding to obtain information for correcting the deficiencies.

TEST MATERIAL

1. 6V53T engine

2. XTG 250 transmission

3. Oil for engine -- MIL-L-2104A, Sup. 1, Grade 30, date (not available).

4. Oil for final drives and transmission -- MIL-L-2104A, Sup.1, Grade 10, date (not available).

5. Fuel -- VV-F-800, Grade DF-2, 17 December 1954.

6. Coolant -- tap water with rust inhibitor.

TEST EQUIPMENT

1. Test Cell No. 5, Bldg. 212, Detroit Arsenal. This cell is 25 feet wide, 45 feet long, and 22 feet in height. Air at velocitie from 3 to 7 mph can be applied. Air temperature can be regulated to a maximum of 160 F. The dynamometer equipment is installed in adjacent cells to minimize interference with air flow through the ce

The following associated equipment of this cell will be used:

a. Blowers and steam heaters to produce vehicle ambient temperatures to 115 F.

b. Load dynamometers with speed increasers; one set for connection to each track sprocket drive shaft, maximum stall torque load -- 68,000 lb. ft., torque load at 15 rpm -- 44,000 lb. ft., maximum shaft speed at high torque ratio -- 360 rpm, maximum shaft speed in direct drive -- 3000 rpm.

c. Controls for applying and balancing the output loads.

d. Chronotachometers, Electric Time Company, Selsyn-Type for output speeds, synchronous type for engine speed.

e. A semi-automatic, electrical typing system for recording pressures, temperatures, and time. It is manually started for each series of recordings.

f. Pressure transducers, vibrotron digital gage, BJ Electronics, Borg-Warner Corporation for measuring air, coolant, and oil pressures.

g. Automatic shut-down system for limits of pressures and temperatures.

2. Barometer, Central Scientific Company

3. Psychrometer, Bendix-Friez, equipped with blower

4. Thermocouples, iron-constantan, ISA type "Y" wire fabricated for measuring air temperatures in open areas.

5. Thermocouples, immersion, iron-constantan, ISA Type "Y" wire for measuring temperatures of engine air, engine coolant, and oil.

6. Velometer for measuring velocity of wind.

TEST PROCEDURE

1. Preparation

a. Drain engine crankcase. Fill with Mil-L-2104A, Sup. 1, Grade 30 oil. Measure and record the amount required to fill to full level.

b. Drain transmission. Fill with Mil-L-2104A, Sup. 1, Grade 10 oil. Measure and record the amount required to fill to full level.

c. Drain engine cooling system. Fill with tap water and rust inhibitor (Spec. No. O I 490 (1)). Measure and record th amount required to fill radiator.

d. Drain fuel tanks. Fill with VV-F-800, Grade DF-2, fuel.

e. Secure thermostat at maximum open position.

f. Install vehicle in Cell 5, Bldg. 212. Remove sprocke and install adapters to connect drive to dynamometer. Align axles with dynamometer shafts. Concentricity shall be within 0.12 inch T.I.R. Angularity of axles shall be within 0.12 inch T.I.R. at a 20-inch diameter. Secure each corner of vehicle to "T" bed with chain hoists.

g. Connect automatic shut-down system to shut-down throttle.

h. Check that governor limits engine speed at 3050 rpm at no load. This will insure operation at 2800 rpm full load with no governor interference.

2. Instrumentation

Provide instrumentation to measure the following:

a. Speed of engine
b. Speed of each sprocket
c. Output torque of each sprocket
d. Velocity of wind
e. Fuel consumption (for initial power test)
f. Temperatures of the following:

(1) Air, vehicle ambient (4)

(2) Air, entering inlet grilles (6)

(3) Air, entering radiator (8)

(4) Air, leaving radiator (8)

(5) Air, entering exit grilles (6)

(6) Air, entering air cleaner

(7) Air, entering turbocharger compressor

(8) Air, air-box

(9) Air, battery ambient
(10) Exhaust gases, entering turbocharger turbine
(11) Exhaust gases, exhaust port, each cylinder (6)
(12) Coolant, leaving engine, each bank (2)
(13) Coolant, entering radiator (at radiator)
(14) Coolant, leaving radiator (at radiator)
(15) Coolant, entering oil cooler
(16) Coolant, leaving oil cooler
(17) Oil, engine sump
(18) Oil, engine gallery
(19) Oil, engine turbine drain
(20) Oil, entering transmission cooler
(21) Oil, leaving transmission cooler
(22) Fuel, leaving tank
(23) Fuel, entering engine

g. Pressures

Pressures of the following:

(1) Air, vehicle ambient
(2) Air, entering radiator
(3) Air, leaving radiator
(4) Air, entering turbocharger compressor
(5) Air, air-box
(6) Coolant, surge tank
(7) Oil, engine gallery
(8) Oil, transmission main
(9) Oil, transmission lube
(10) Fuel, leaving second filter (entering injection pumps)

3. Specified Limits

Stop testing before exceeding the following limits:

a. Coolant, entering radiator: 230 F
b. Oil, engine sump: 285 F
c. Oil, leaving transmission: 300 F
d. Exhaust, turbine inlet: 1350 F

Tests

a. Power Performance Test

Determine power and fuel economy under the following conditions:

(1) Ambient temperature of vehicle: 115 ± 5 F
(2) Wind velocity: 5 ± 2 mph
(3) Direction of wind: head
(4) Transmission speed ratio: first gear
(5) Engine power: maximum
(6) Lock-up operation: engine speeds 2800, 2600, 2400, 2200, and 2000 ± 10 rpm
(7) Torque converter operation: From 0.8 to 0.3 ratio (maximum temperature limits not to be exceeded)

b. Stall Test

Perform stall test as follows:

(1) Shift transmission to fourth gear.
(2) Apply brakes.
(3) Open throttle to maximum power position.
(4) Measure speed of engine when temperature of transmission outlet oil has increased to 275 F.

Perform stall test before and after each cooling tes

c. Cooling Test No. 1

Remove equipment for measuring fuel consumption. Install original piping.

Conduct cooling test under the following conditions:

(1) Ambient temperature of vehicle: *115 ± 3 F
(2) Wind velocity: 5 ± 2 mph
(3) Direction of wind: head
(4) Transmission gear: first
(5) Engine power: maximum
(6) Transmission: in lock-up
(7) Engine speed: 2800, 2600, 2400, 2200 and 2000 ± 10 rpm
(8) Condition of vehicle: All grille doors and hatches closed.

After stabilization of engine coolant, engine oil, and transmission oil temperatures, continue test for 15 minutes. Record data at start of stabilized period and after each five-minute interval.

*If the vehicle does not cool, the ambient temperature will be reduced to the value where the vehicle will cool.

d. Cooling Test No. 2

Conduct cooling test under the same conditions for Cooling Test No. 1, except torque converter shall be operated from 0.8 to 0.3 speed ratios in increments of 0.1. Discontinue testing if critical temperatures exceed limits.

e. Investigation Tests

If the cooling system is inadequate, tests will be conducted to obtain information for correcting the deficiencies.

f. Miscellaneous Information

(1) Measure and record all oil and water added during project.

(2) Conduct observations of the cooling system for the following:

(a) Any difficulties in filling the system such as air entrainment.

(b) Aeration

(c) Leaks

(d) Overflow. Record amount of overflow.

(3) Observe and record any difficulties encountered in starting and stopping engine under hot conditions.

(4) Investigate and record all deficiencies.

TEST RESULTS

The data shall be summarized by charts showing temperatures of coolant, engine oil, and transmission oil for each test condition with respect to output speed. If the cooling system is inadequate, the data shall be analyzed to determine nature of deficiencies. All other deficiencies of the power package shall be reported. Pertinent information of performance shall be included in the report.

Test Program No. 575 11 July 1962

JOB ASSIGNMENTS

The Instrument-Electrical Laboratory shall check out and calibrate the instrumentation, and shall be responsible for initia accuracies.

The Power Plant Laboratory shall be responsible for installin the test setup, conducting the tests, recording the data, and presenting the report.

TEST PROGRAM

Any deviations from this Test Program shall be agreed upon by the Project Engineer and Chief of Power Plant Laboratory.

Concurrence:

Daniel Ewashenko DEB

DANIEL EWASHENKO
Project Engineer - Ext. 25-226

Prepared by:

Arthur L. Jaeger, Jr.

ARTHUR L. JAEGER, JR.
Test Engineer - Ext. 28-216

Approved by:

Lee A. Smith

LEE A. SMITH
Chief, Power Plant Laboratory

Edward J. Rambie

EDWARD J. RAMBIE
Chief, Fluid Flow Section

Edward R. Lukovich for

LUDWIG I. LEHTO
XM 551 Vehicle Project Engr.
Ext. 33-235

Inclosure 1

Inclosure No. 2

TEST DESCRIPTION	a	b	c	d	e	f	g	h	i	j	k	l	m
Engine Speed, RPM	2797	2601	2400	2197	2000	2486	2386	2283	2270	2224	2178	2146	2122
Sprocket Speed, RPM	388	360	332	306	279	266	240	201	193	174	145	125	92
Sprocket Torque, LB FT	2420	2575	2730	2785	2785	3050	3360	3810	4020	4200	4650	4940	5780
Sprocket Power, HP	182	180	176	165	151	157	155	148	149	141	129	118	102
Converter Speed Ratio	LU	LU	LU	LU	LU	.76	.72	.63	.61	.56	.48	.42	.31
B.S.F.C. LB/HP Hr	.53	.50	.48	.46	.47	.53	.54	.56	.55	.54	.57	.63	.73
Air Ambient, F	113	110	113	111	112	115	118	118	113	118	113	110	111
Fuel Entering Eng.,F	106	106	104	103	104	107	112	108	103	108	107	109	106

Notes:
1. Load - Full
2. Driving Range-3RD
3. Fuel - VV-F-800,DF2
4. Fuel From Laboratory Tank
5. Fan Automatic Speed Control Removed

SUMMARY OF XM-551 VEHICLE

PERFORMANCE RESULTS

TABLE I

Inclosure 3

TEST DESIGNATION	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
ENGINE SPEED, RPM	2805	2599	2399	2206	2001	2576	2322	2229	2159	2096	2063	2134	2796	2798	2119	2106
SPROCKET SPEED, RPM	389	360	333	306	278	292	230	191	155	121	90	90	388	388	119	107
SPROCKET POWER, HP	175	173	170	161	148	142	147	140	127	111	93	103	175	167	112	99
CONVERTER SPEED RATIO	LU	LU	LU	LU	LU	.81	.71	.62	.52	.41	.31	.30	LU	LU	.40	.36
GUN POSITION	REAR	REAR	REAR	REAR	REAR	REAR	REAR	REAR	REAR	REAR	REAR	REAR	FRONT	FRONT	FRONT	FRONT
AIR AMBIENT, F	115	115	115	115	115	115	116	116	116	116	116	85	116	115	115	115
AIR AMB. PRESS., IN. H_2O	-.7	-.6	-.5	-.7	-.7	-.7	-.6	-.5	-.5	-.5	-.5	-.5	-.5	-.7	-.7	-.7
AIR ENT. INLET GRILLES, F	115	115	115	115	115	115	116	117	116	116	116	85	116	115	115	115
AIR ENTERING RADIATOR, F																
TOP LEFT	128	127	126	126	129	129	129	129	130	131	132	101	125	126	128	130
TOP MIDDLE	121	120	119	122	122	122	122	124	123	124	123	94	117	118	119	120
TOP RIGHT	151	139	133	133	134	138	137	137	139	141	145	114	131	139	143	144
CENTER LEFT	119	120	120	122	121	121	122	124	124	124	125	91	118	118	119	119
CENTER RIGHT	117	117	116	118	117	117	117	120	119	119	119	89	117	118	117	118
BOTTOM LEFT	137	137	136	137	140	145	141	143	142	144	146	112	136	137	140	143
BOTTOM MIDDLE	172	167	158	161	163	169	165	165	169	170	173	147	162	165	175	181
BOTTOM RIGHT	151	144	146	146	149	150	152	154	155	157	161	130	134	147	148	149
AIR LEAVING RADIATOR, F																
TOP LEFT	186	175	178	178	186	190	187	194	192	198	204	173	178	186	193	196
TOP MIDDLE	167	162	159	161	165	170	169	174	174	178	180	148	160	166	173	181
TOP RIGHT	172	168	167	169	171	179	177	179	181	186	192	160	170	172	183	185
CENTER LEFT	172	170	168	169	171	181	177	179	181	186	192	160	170	172	183	186
CENTER RIGHT	168	166	164	165	166	176	173	175	177	182	187	155	169	171	180	184
BOTTOM LEFT	192	189	188	189	194	204	199	201	204	209	218	186	192	194	207	210
BOTTOM MIDDLE	189	186	185	185	186	199	195	197	201	206	214	183	185	190	204	206
BOTTOM RIGHT	187	185	183	184	186	199	195	197	200	205	214	182	186	187	202	205
AIR LVG. EXHAUST GRILLE, F																
FRONT LEFT	178	174	173	173	175	185	181	183	186	190	196	164	174	175	183	185
FRONT MIDDLE	181	176	173	173	173	185	181	182	185	188	195	163	176	174	184	187
FRONT RIGHT	177	174	170	170	171	183	178	179	182	186	193	164	174	178	183	187
REAR LEFT	182	179	182	181	182	194	190	192	194	197	204	169	184	184	190	193
REAR MIDDLE	205	201	188	188	186	203	198	200	204	209	215	191	196	206	213	218
REAR RIGHT	178	175	173	173	174	183	182	183	186	191	195	162	177	176	182	184
AIR ENT. AIR CLEANER, F	129	127	129	129	128	132	139	134	141	142	144	113	124	132	123	123
AIR ENT. TURBOCHARGER, F	138	137	137	138	138	143	142	143	144	147	149	126	134	135	138	140
AIR BOX, F	311	290	272	257	247	297	274	267	263	262	264	240	310	309	258	260
AIR BOX PRESSURE, IN. HG.	26	22	18	15	13	21	17	16	15	14	13	16	26	25	15	14
AIR BATTERY BOX, F	171	171	164	165	167	174	168	172	175	179	183	155	170	174	168	176
AIR ABOVE TRANS. LEFT, F	183	172	169	171	171	181	178	180	182	187	192	162	173	175	192	186
AIR ABOVE TRANS. RIGHT, F	185	182	178	179	181	193	187	191	193	197	204	173	183	186	194	199

NOTES:
1. LOAD - FULL
2. DRIVING RANGE - 3RD
3. FUEL - VV-F-800, DF 2
4. FUEL FROM VEHICLE TANKS
5. FAN AUTOMATIC SPEED CONTROL REMOVED
6. COOLANT THERMOSTAT BLOCKED OPEN

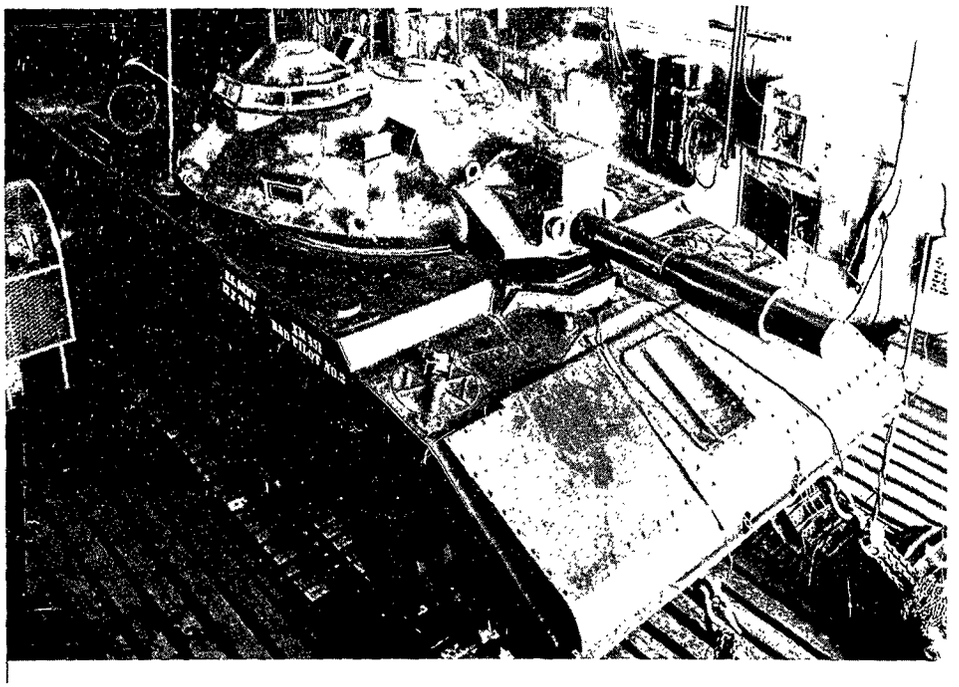
SUMMARY OF XM-551 VEHICLE COOLING RESULTS
TABLE II, PART 1 OF 2 PARTS

Inclosure 3-2

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
COOLANT LEAVING ENGINE, F																
RIGHT BANK	197	194	192	195	191	207	203	204	207	213	221	191	194	196	209	214
LEFT BANK	195	192	191	192	194	209	204	205	209	215	223	192	196	197	212	215
COOLANT ENT. RADIATOR, F	195	192	191	192	194	207	204	205	209	215	223	192	196	197	212	215
COOLANT LVG. RADIATOR, F	183	182	181	181	183	195	192	193	197	201	208	177	186	187	198	201
COOLANT ENT. COOLER, F	186	183	182	183	184	196	193	194	196	201	208	177	185	184	198	202
COOLANT LVG. COOLER, F	189	185	184	185	187	202	198	198	203	209	217	186	189	190	204	208
COOLANT SURGE TANK PRESSURE, PSI	5	4	7	7	7	9	11	11	11	10	10	6	7	5	8	8
OIL ENGINE SUMP, F	253	248	247	243	243	262	257	254	256	261	268	242	255	254	258	261
OIL ENGINE TURBO DRAIN, F	279	273	266	263	260	282	275	274	276	279	285	262	280	277	280	282
OIL ENGINE GALLERY PRESSURE, PSI	51	51	55	55	53	54	53	53	52	51	50	52	56	54	47	47
OIL ENTERING TRANS., F	206	202	200	202	200	236	229	232	240	254	273	253	205	215	250	257
OIL ENTERING TRANS., PRESSURE, PSI	26	25	25	25	24	34	33	32	32	31	30	33	27	24	32	32
OIL LEAVING TRANS., F	229	224	221	213	219	267	252	256	268	289	316	300	228	235	289	300
OIL TRANS. MAIN PRESSURE, PSI	159	163	169	174	179	179	188	193	189	173	157	174	159	159	171	165
FUEL LEAVING TANK, F	146	149	141	141	144	149	150	154	158	163	172	140	142	156	140	146
FUEL ENTERING ENGINE, F	161	161	153	154	156	164	156	160	164	169	179	145	156	169	155	160
FUEL PRESSURE, PSI	57	56	57	57	56	56	56	56	55	55	55	56	57	56	57	57
GASES LEAVING CYLINDERS, F																
RIGHT BANK FRONT	870	850	830	780	740	880	830	790	780	780	770	740	——	870	770	770
RIGHT BANK MIDDLE	960	940	950	920	860	970	950	940	920	900	900	900	960	960	910	910
RIGHT BANK REAR	990	960	950	920	890	990	960	950	930	930	930	900	990	990	925	930
LEFT BANK FRONT	870	825	800	800	810	840	800	810	810	810	820	770	860	860	800	800
LEFT BANK MIDDLE	870	860	880	880	890	890	900	890	880	900	900	880	880	870	900	900
LEFT BANK REAR	960	970	970	980	980	980	980	990	990	1000	990	950	960	960	990	995
GASES ENTERING TURBO-CHARGER, F	1000	990	980	970	980	1000	1000	990	990	1000	1000	960	1000	1000	990	990

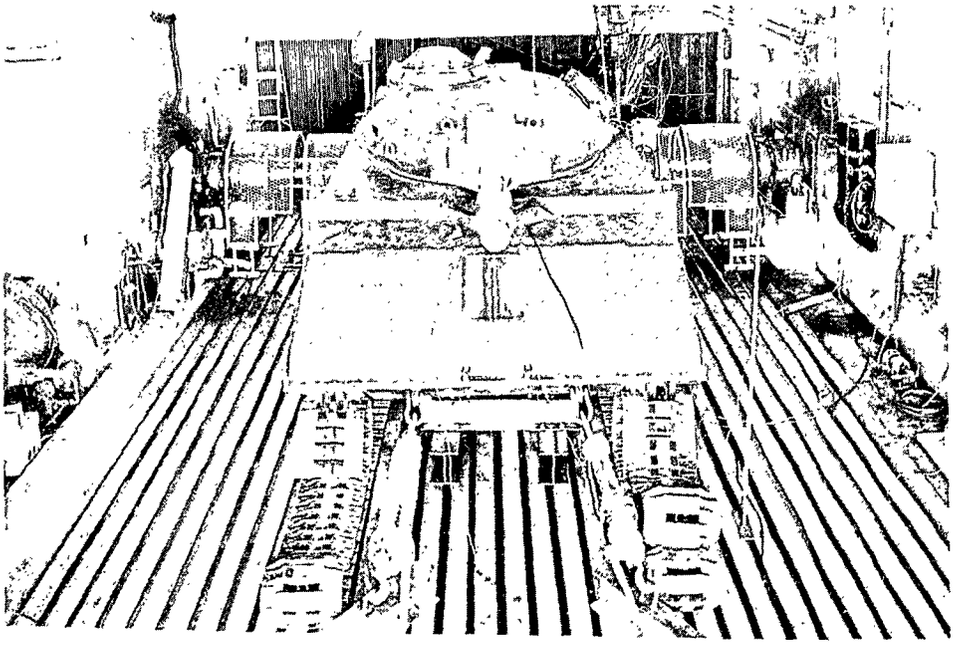
NOTES:
1. LOAD - FULL
2. DRIVING RANGE - 3RD
3. FUEL - VV-F-800, DF 2
4. FUEL FROM VEHICLE TANKS
5. FAN AUTOMATIC SPEED CONTROL REMOVED
6. COOLANT THERMOSTAT BLOCKED OPEN

SUMMARY OF XM-551 VEHICLE COOLING RESULTS
TABLE II, PART 2 OF 2 PARTS



XM-551 VEHICLE, RIGHT FRONT VIEW

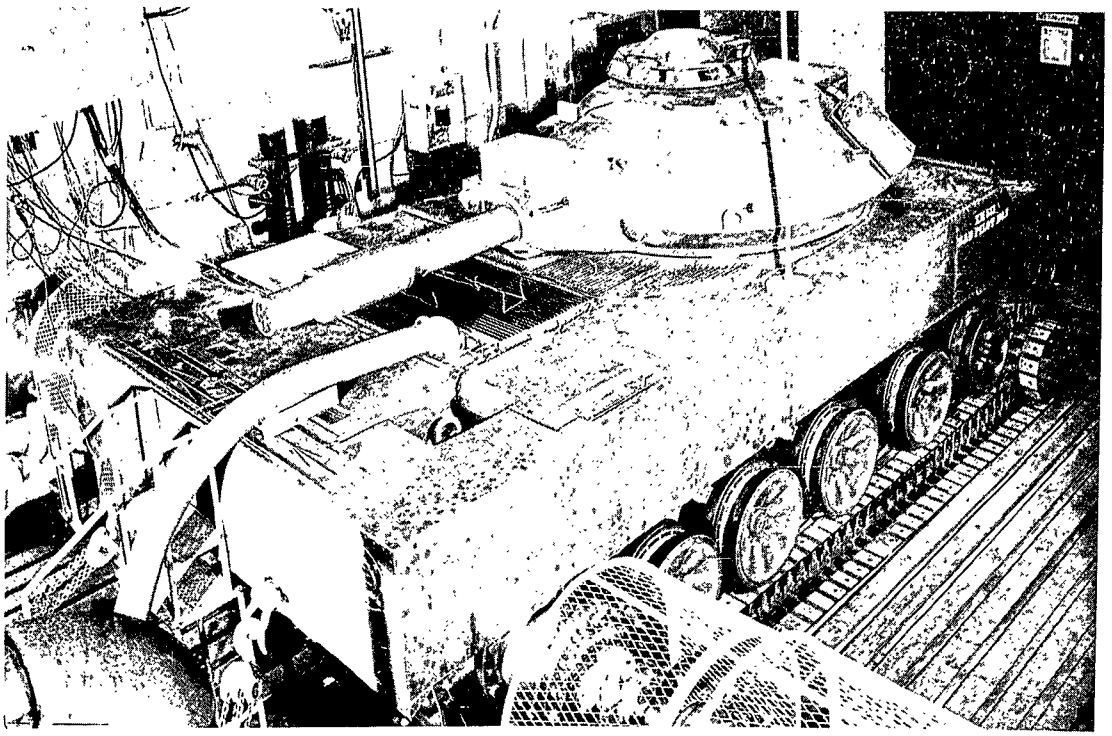
FIGURE 1



XM-551 VEHICLE, FRONT VIEW

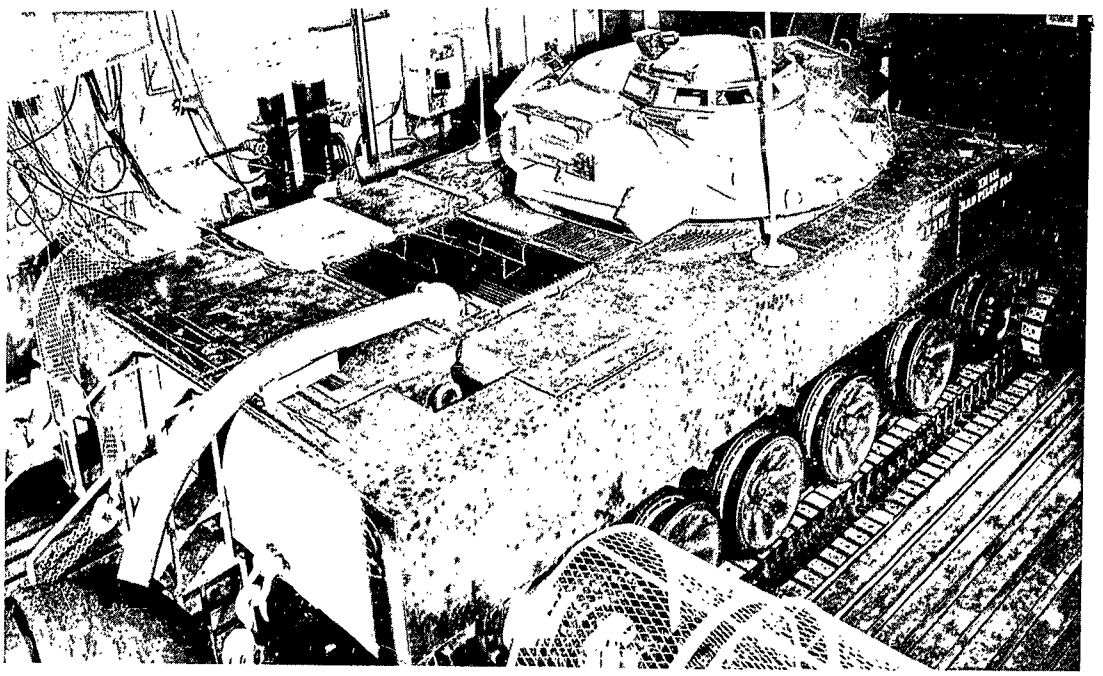
FIGURE 2

Inclosure 4



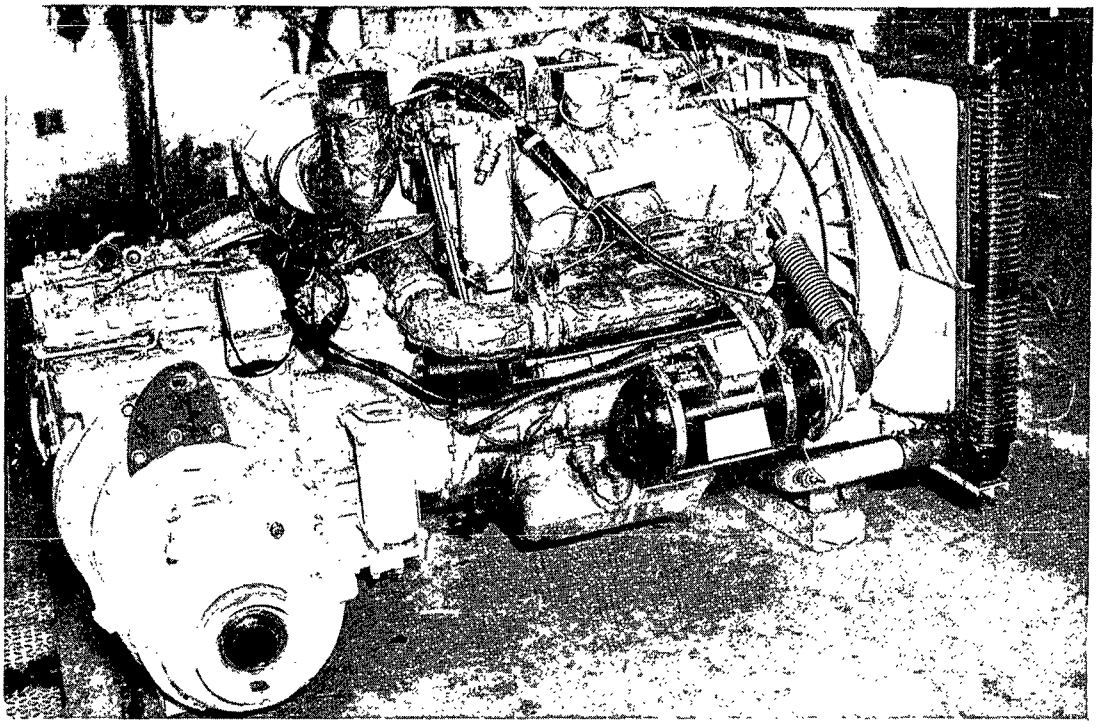
XM-551 VEHICLE, RIGHT REAR VIEW, GUN TO THE REAR

FIGURE 3



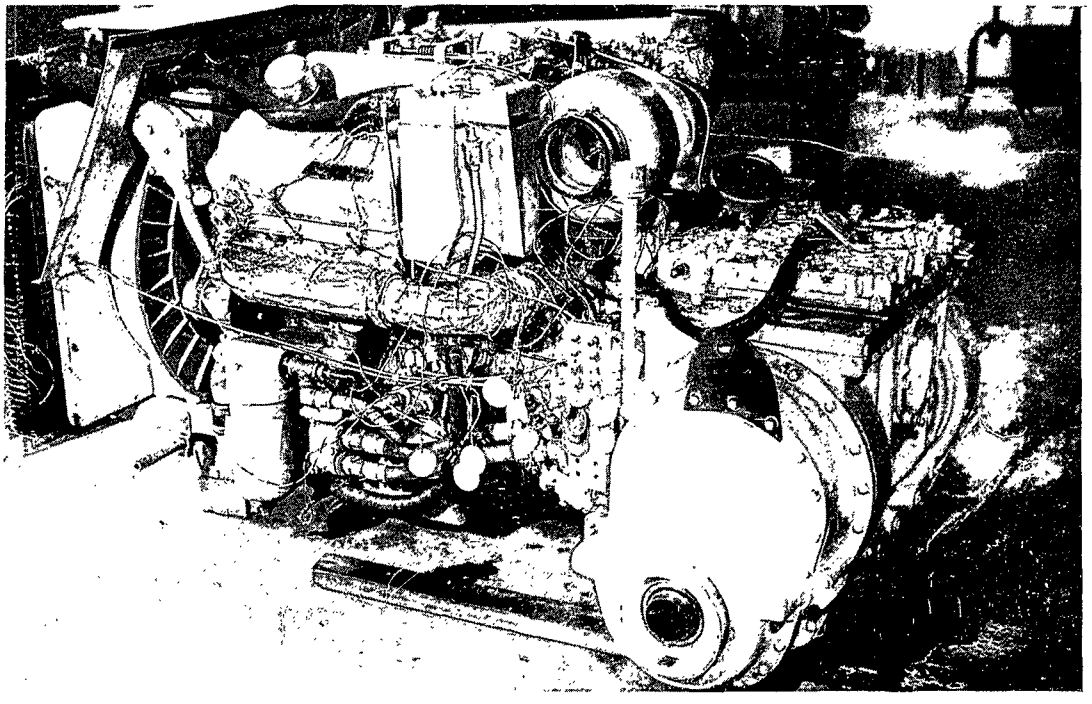
XM-551 VEHICLE, RIGHT REAR VIEW, GUN FORWARD

FIGURE 4



XM-551 POWER PACKAGE, RIGHT VIEW

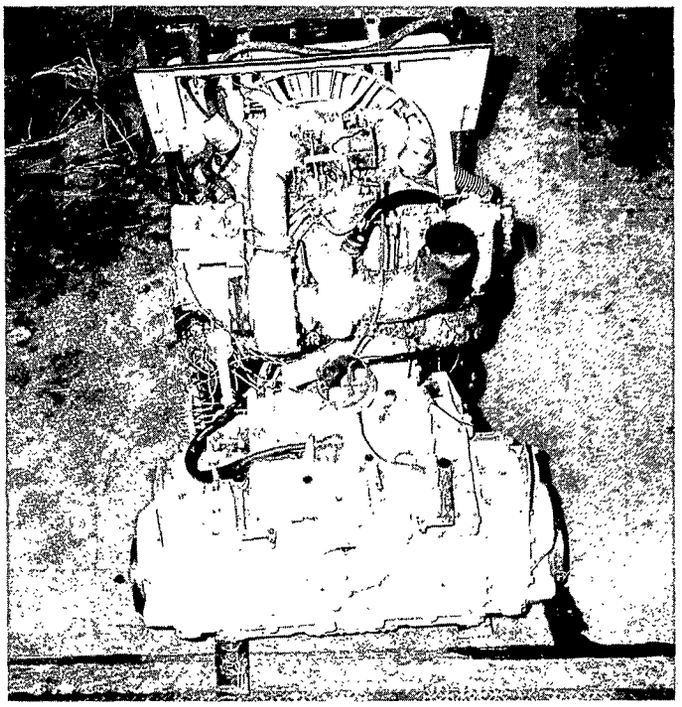
FIGURE 5



XM-551 POWER PACKAGE, LEFT VIEW

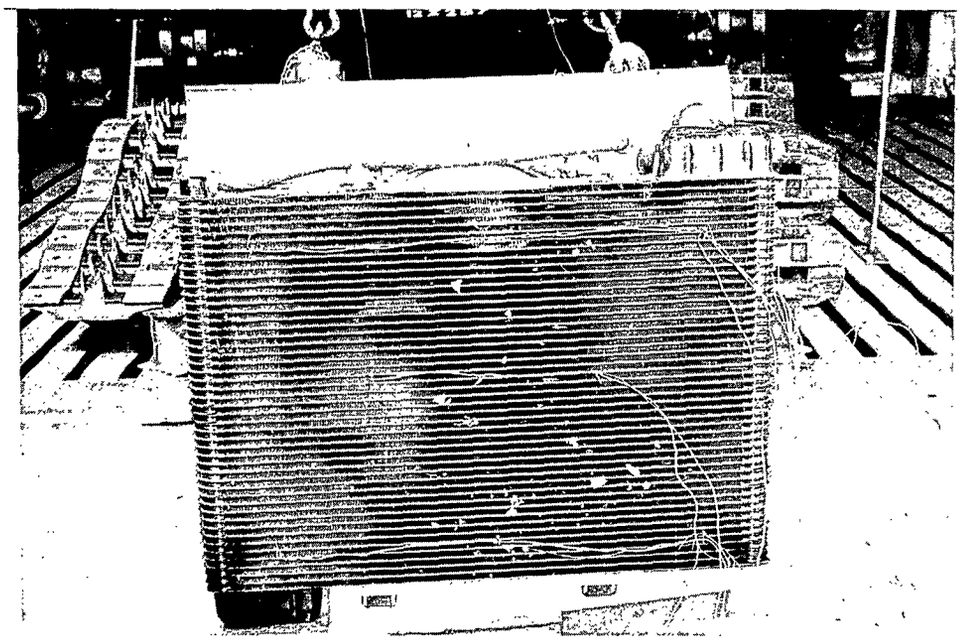
FIGURE 6

Inclosure 6



XM-551 POWER PACKAGE, TOP VIEW

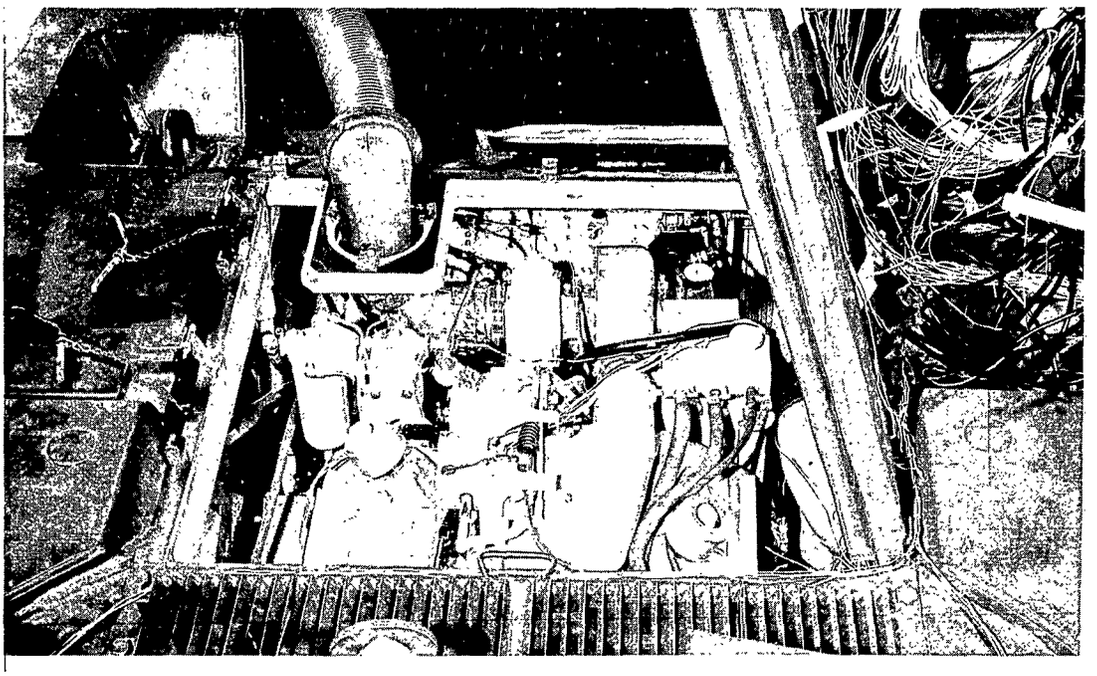
FIGURE 7



XM-551 RADIATOR, UPSTREAM VIEW

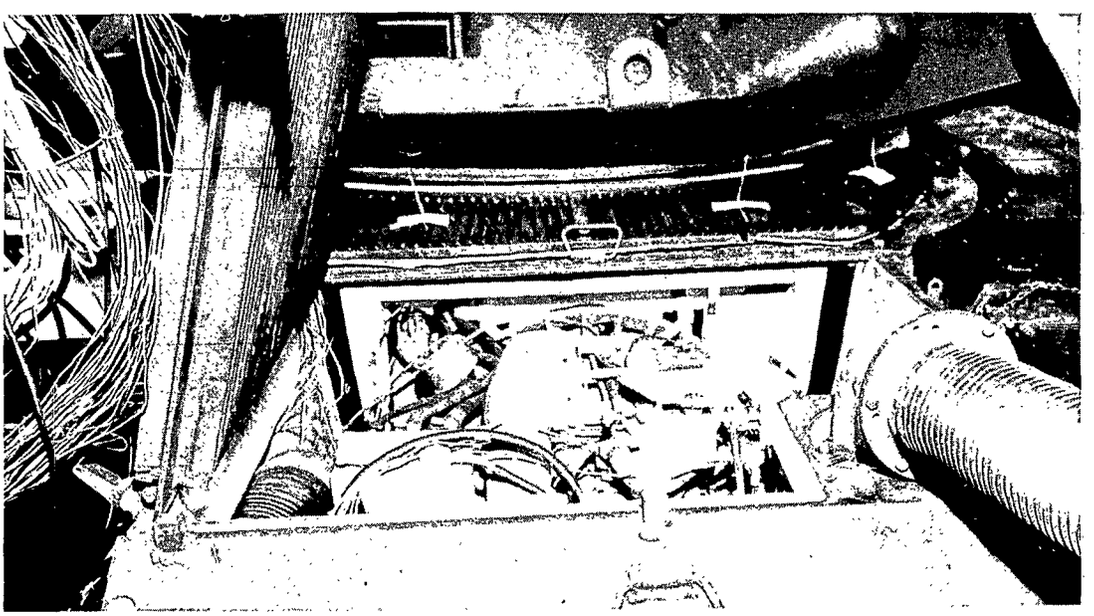
FIGURE 8

Inclosure 7



XM-551 POWER PACKAGE INSTALLED IN HULL,
VIEWED FROM TURRET

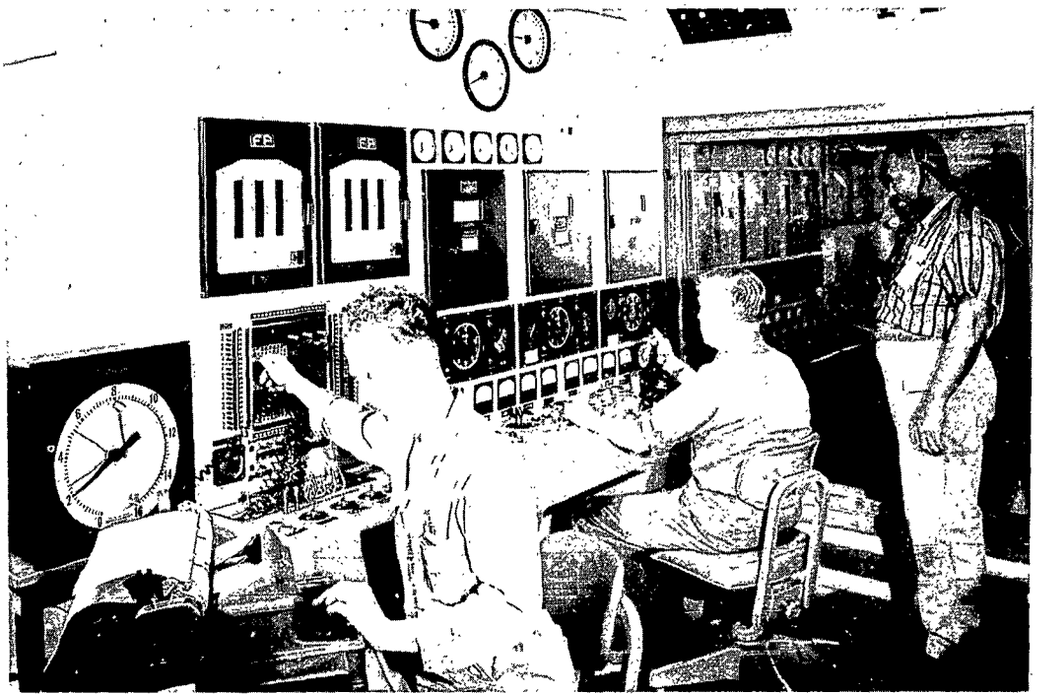
FIGURE 9



XM-551 POWER PACKAGE INSTALLED IN HULL,
VIEWED FROM VEHICLE REAR

FIGURE 10

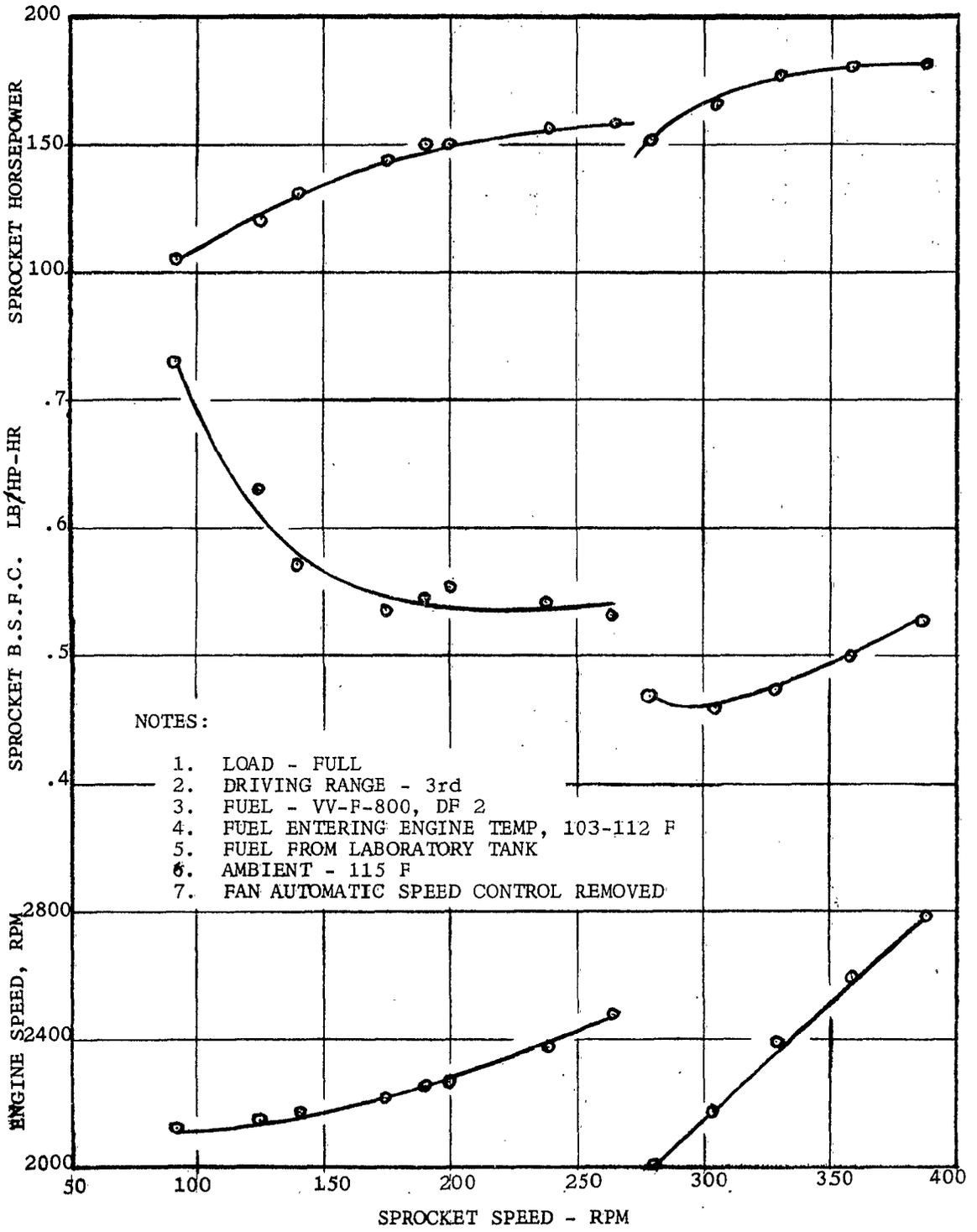
Inclosure 8



TEST CELL CONTROL ROOM

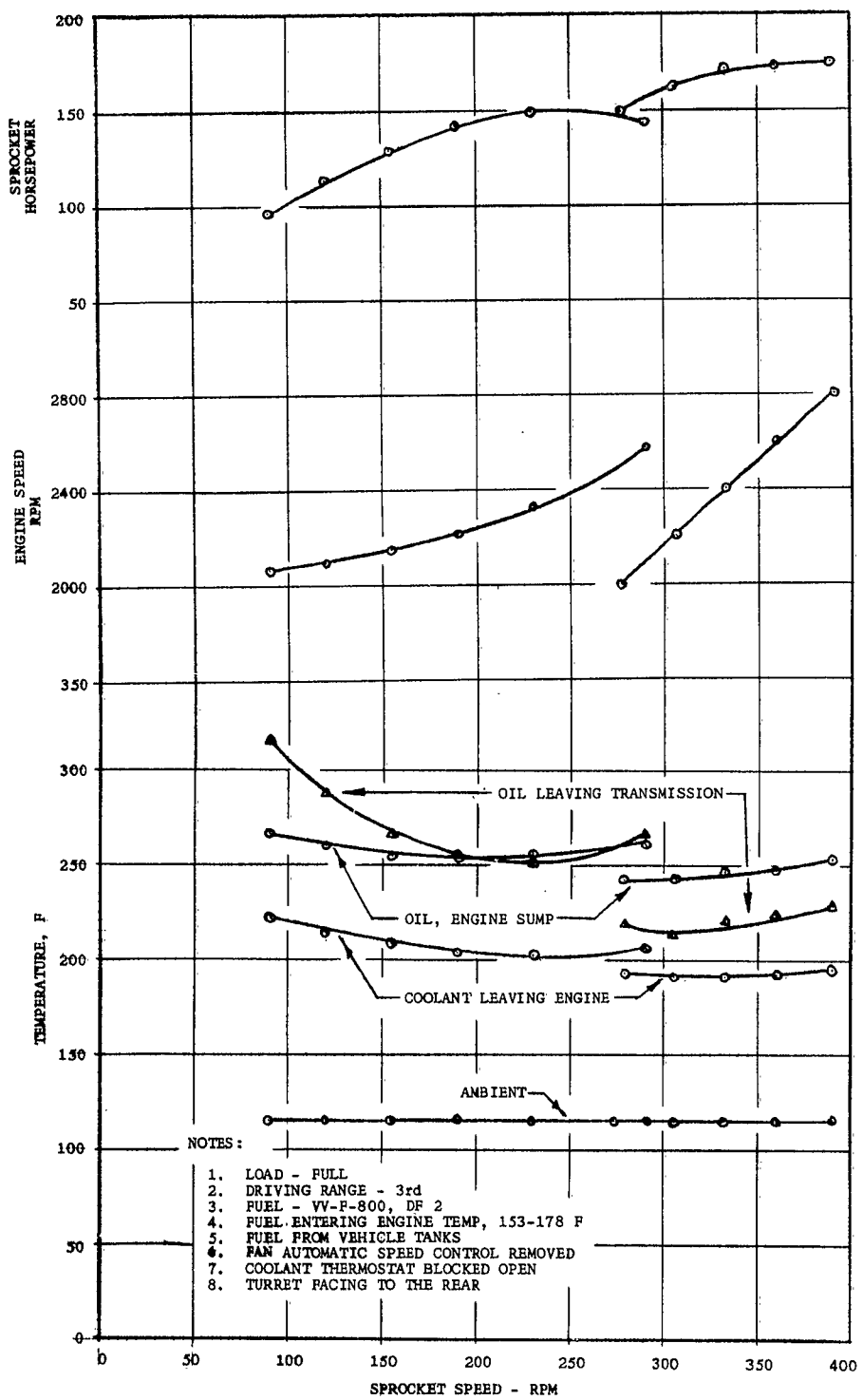
FIGURE 11

Inclosure 9



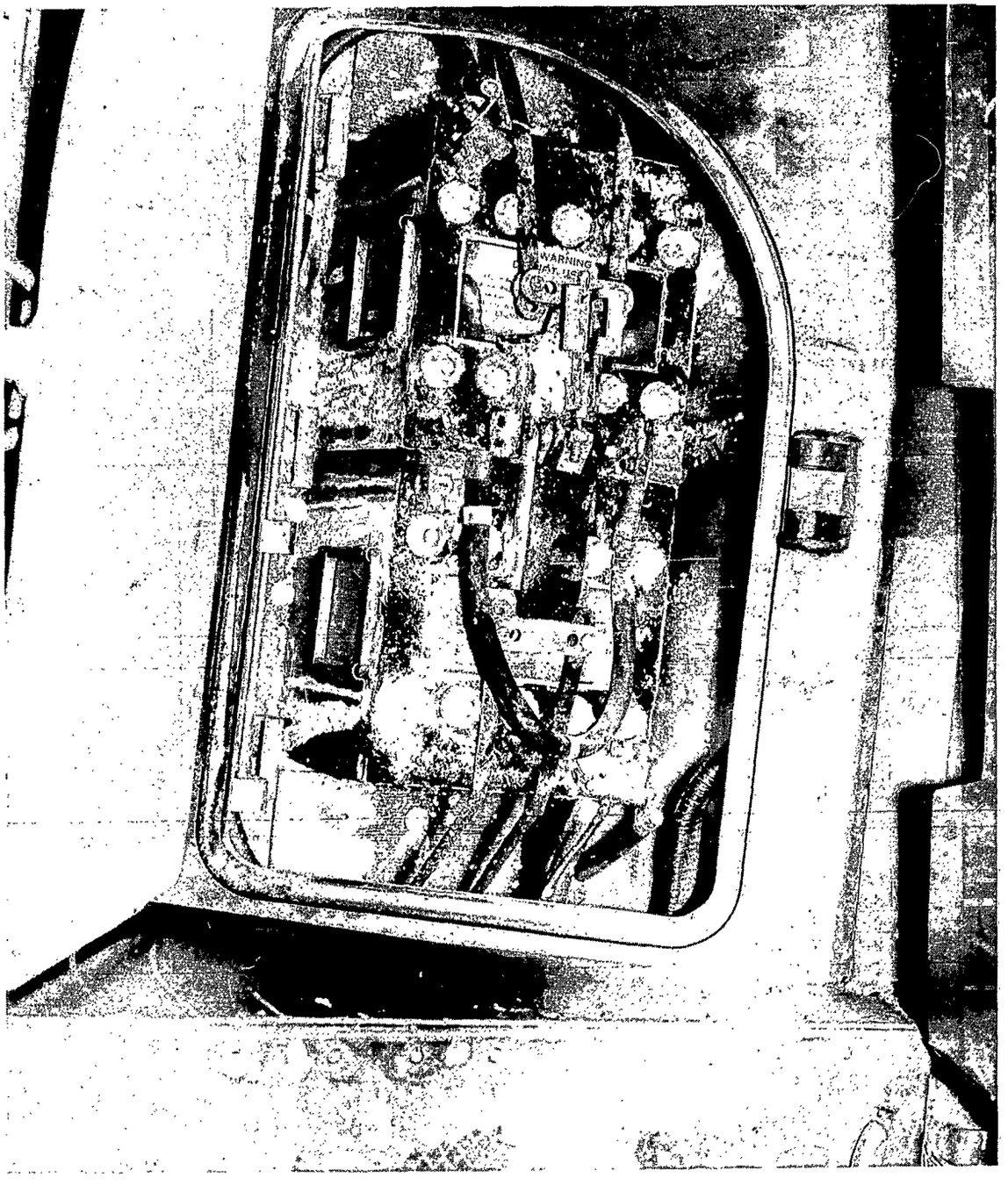
PERFORMANCE CHARACTERISTICS OF XM-551 VEHICLE
FIGURE 12.

Inclosure 10



COOLING CHARACTERISTICS OF XM-551 VEHICLE
FIGURE 13

Inclosure 11



XM-551 VEHICLE BATTERIES AFTER COOLING TESTS

FIGURE 14

Inclosure 12

OO FORM 1062
14 MAR 47
(FORMERLY [illegible])

ORDNANCE DEPARTMENT

EXPENDITURE ORDER

EXPENDITURE ORDER NO.	
3517-03XX	BASIC
DATE	
9 AUGUST 1962	

IMShear/bg/33284

SUBJECT: COOLING & PERFORMANCE TEST OF AN AR/AAV VEHICLE

OMS CODE & TITLE: 5510.12.20300.01 ARMORED RECONNAISSANCE AIRBORNE ASSAULT VEHICLE

ACCOUNTING CLASSIFICATION:	TARGET OBLIG DATE	REPORT CODE
21X2040 364-6129 P5510 S20-089	31 Dec 1962	"A"

PRON NO.: 24-3-1R104-03-24-DE — PRIORITY "A"

FUND CERTIFICATION: FUNDS HAVE BEEN RESERVED FOR THIS ORDER IN THE AMOUNT OF

F. BIGLEY, LT COL, FC, FINANCE & ACCOUNTING OFFICER

8-9-62

FUNDS AUTHORIZED: CURRENT:

8/9/62

THIS EXPENDITURE ORDER IS INITIALLY SCHEDULED AS FOLLOWS:

a. PLANNED STARTING DATE: AUGUST 1962

b. TARGET COMPLETION DATE: DECEMBER 1962

REF: AOS-20, #68-63, CHG 2

DIST: Lab Div. - 6
Sup Serv. - 1
Res & Eng. - 5
Rev & Anal. - 1
Fin & Acctg. - 1
Plans & Prog. - 2

PROCUREMENT AUTHORITY	OO FILE	EXPENDITURE ORDER NO. 3517-03XX BASIC Page 1 of 2 Pages	ROBERT BRUCE, COMPTROLLER
APPROPRIATION	ARSENAL FILE		

Inclosure 13

DET ARS EX ORDER 3517-0332

LABORATORIES DIVISION

1. SUPPLY THE NECESSARY LABOR AND TEST EQUIPMENT TO SETUP AND CONDUCT A COOLING AND PERFORMANCE TEST OF AN AR/AAV, TO BE FURNISHED BY THE PROJECT ENGINEER.

2. INFORMAL REPORT REQUIRED.

2. PROJECT ENGINEER: : Mr. C. B. SALTER, EXT. 20202

3. PROGRAM AUTHORIZATION: JR 8/9/62

LABOR "11" (APPROX.

MATERIAL "99" 8/9/62 mb

REF: COST EST #2811.

Inclosure 13-2

AD _____ ACCESSION NO. _____ UNCLASSIFIED

Power Plant Laboratory, Laboratories Division, Detroit Arsenal - COOLING AND PERFORMANCE CHARACTERISTICS OF THE XM-551 ARMORED RECONNAISSANCE AIRBORN ASSAULT VEHICLE. Arthur L. Jaeger, Jr. XM-551 Cooling Test

Report No. 7746, 15 pp - Illus - Tables, Graphs - Unclassified Report APR 17 '63

(1) Purpose: Determine at 115 F ambient the performance and cooling characteristics of the XM-551 vehicle.
(2) Method: High-ambient performance and cooling tests were conducted at full-rack, 3rd driving range with a 3-5 mph headwind.
(3) Results and Conclusions: a. Maximum observed sprocket horsepower was 182 at 2797 rpm engine speed with transmission in 3rd driving range, lockup. b. The vehicle at full-fuel rack cooled at 115 F ambient with the transmission in third driving range at all design operating speeds. The coolant thermostat was blocked open and the fan automatic speed control removed. The highest lockup temperatures were obtained at an engine speed of 2798 rpm. Engine sump oil, coolant leaving the engine and oil leaving the transmission were 254 F, 197 F and 235 F at 115 F ambient. The highest converter temperatures were observed at the lowest converter ratio. At a converter speed ratio of .36, engine sump oil, coolant leaving the engine and oil leaving the transmission were 261 F, 215 F and 300 F at 115 F ambient. At a converter speed ratio of .56, engine sump oil, coolant leaving the engine, and oil leaving the transmission were 255 F, 207 F and 262 F at 116 F ambient. A .56 converter ratio is the ratio at the minimum design vehicle operating speed of 2½ miles per hour with the transmission in first driving range.

AD _____ ACCESSION NO. _____ UNCLASSIFIED

Power Plant Laboratory, Laboratories Division, Detroit Arsenal - COOLING AND PERFORMANCE CHARACTERISTICS OF THE XM-551 ARMORED RECONNAISSANCE AIRBORN ASSAULT VEHICLE. Arthur L. Jaeger, Jr. XM-551 Cooli Test

Report No. 7746, 15 pp - Illus - Tables, Graphs - Unclassified Report APR 17 '63

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AD _____ ACCESSION NO. _____ UNCLASSIFIED

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